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# An investigation of how culture impacts global work: Unpacking the layers of culture

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# AN ONTOLOGY-DRIVEN TOPIC MAPPING APPROACH TO MULTI-LEVEL MANAGEMENT OF E-LEARNING RESOURCES

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## Abstract

*An appropriate use of various pedagogical strategies is fundamental for the effective transfer of knowledge in a flourishing e-learning environment. The resultant information superfluity, however, needs to be tackled for developing sustainable e-learning. This necessitates an effective representation and intelligent access to learning resources. Topic maps address these problems of representation and retrieval of information in a distributed environment. The former aspect is particularly relevant where the subject domain is complex and the later aspect is important where the amount of resources is abundant but not easily accessible. Conversely, effective presentation of learning resources based on various pedagogical strategies along with global capturing and authentication of learning resources are an intrinsic part of effective management of learning resources. Towards fulfilling this objective, this paper proposes a multi-level ontology-driven topic mapping approach to facilitate an effective visualization, classification and global authoring of learning resources in e-learning.*

*Key words: Ontologies, Topic Maps, E-learning, Knowledge Management*

# AN ONTOLOGY-DRIVEN TOPIC MAPPING APPROACH TO MULTI-LEVEL MANAGEMENT OF E-LEARNING RESOURCES

## 1 INTRODUCTION

E-learning is “the delivery of educational content via electronic media” (Tastle, White & Shackleton, 2005) (p. 242). To improve the effectiveness of e-learning, the constructivist learning paradigm (Papert, 1990) proposes utilizing multiple student-centred learning strategies including collaborative learning, explorative learning, adaptive learning, and concept mapping for facilitating the smooth transferring of knowledge in knowledge construction. While these strategies do assist learners with their knowledge construction, they also create a problem of information overloading due to an enormous amount of learning resources generated (Vivek, Steven, Dennis, Gretchen, 2007). Such information overloading prevents learners from effectively wading through this superfluity of information in an e-learning environment. As a result, a well-organized representation of course concepts, learning resources, learning tools for facilitating the effective and efficient use of learning resources is essential for successful e-learning.

Numerous developments have emerged using ontologies and semantic web technologies for addressing these problems (Jin et al., 1999, Nejdil et al., 2002, Anderson & Whitelock, 2004, Sampson et al., 2004, Dicheva & Dichev, 2006, Gasevic & Hatala, 2006). These developments, however, have not yet been fully incorporated into the existing e-learning scenario due to the challenges involved in implementing them. Existing e-learning websites are still predominantly based on the first generation of learning management systems (LMS) such as blackboard, WebCT, Top class, Learning space, Virtual Laboratory, FirstClass, Moodle and others. These systems do not support for effective management of e-learning resources (Hatem, Ramadn & Neagu, 2005). The reason for this is that these systems are created for human and machine readability but not for computer understandability. To effectively manage learning resources, improving machine understandability and enabling intelligent information processing are critical.

Semantic web is a promising solution to enable intelligent web-based information processing (Berners-Lee, Handler & Lassila, 2006). Realizing the potentials of semantic web technologies in education, initiatives using semantic web technologies in e-learning started in late 90's (Jin et al., 1999, Nejdil et al., 2002, Nilsson, Palmer & Brase, 2003). The major argument for this is that the availability of massive information is of no use, unless the ‘right information in the right context with the right level of details to the right person at the right time’ (Holger, 2003) is delivered. There are further developments towards addressing the problems of information representation, retrieval and reuse including topic mapping (Mizoguchi, 2004, Vatant, 2004, Dicheva et al., 2006) and resource description formatting (RDF) (Garshol, 2004, Yang et al., 2006).

Regardless of these developments in using topic mapping and ontologies in e-learning, very little or no evidence is presented to confront specific issues that online learners face. These critical issues include simple and flexible visualization (Dicheva, Dichev & Dandan, 2005b) and representation of e-learning resources, single point access to all learning resources (Dicheva et al., 2005c), and quality assured sustainable resources for reusability (Brase & Nejdil, 2003). The need to address these issues is further reinforced by the recognition of the stakeholders on the critical importance of a proactive use of diagrammatic representation of course content and effective management of learning resources for successful e-learning (Sridharan, Deng & Corbitt, 2008).

This paper proposes a novel approach for topic visualisation, representation and authoring features to fulfil specific e-learning requirements by extending our earlier work on the identification of critical success factors for sustainable e-learning (Sridharan et al., 2009). In particular, this paper introduces a new dimension to knowledge representation of learning resources based on pedagogies employing topic mapping paradigm. This helps learners create their mental models by choosing the learning path

based on their learning styles and preferences and allows them follow a step-by-step process in their knowledge accumulation processes. Furthermore, the proposed approach enables a sustainable learning object repository, proactive contribution of learning resources with authentication facility.

The remainder of the paper is organized as follows. In Section 2, the research questions and significance of the research are covered. A description of the theoretical background followed by a brief review of related work is presented in Section 3. An ontology-driven topic mapping approach is presented in Section 4. Finally a summary with future research is included in Section 5.

## **2 RESEARCH QUESTIONS**

A massive amount of learning resources is generated through various pedagogic strategies in the current e-learning environment. Some of these resources are generated using disparate learning tools such as discussion forums, e-mails, chat, open courseware materials, useful links etc. Such a rich collection of learning resources provides learners with numerous opportunities for reinforcing and strengthening their learning through effective knowledge construction. It, however, comes with various shortcomings including (a) ineffective use of available learning resources, (b) absence of facilities to capture valuable tacit and explicit knowledge generated, (c) scarcity of time and effort required by domain expert to capture and maintain these resources, and (d) deviation of learners from their mainstream learning activity while trying to interact with multiplicity of tools and technologies associated with an online course.

Against this background, the main question for this research is ‘how to realize effective transfer of knowledge through efficient capturing, eliciting, organizing, authenticating, retrieving reusing learning resources in an e-learning environment?’. Following this question, several subsidiary questions can be defined as follows: (a) How to represent resources in a way that is easy and fast for learners to intuitively comprehend the course concepts? (b) How to provide a single point access to course resources and tools supporting various learning strategies? (c) How to represent the retrieval results in an organised manner based on pedagogic strategies? (d) How to create sustainable learning resources through global authoring of learning resources with authentication facilities?

To answer these questions, this paper proposes a multi-level course visualization and representation approach through considering an ontology-driven single point entry to e-learning resources through topic mapping. The proposed approach has the following specific features including (a) simple multi-level representation of course material both graphically and textually using topic mapping in a taxonomical manner with provision to expand and collapse based on the selection of a branch by the learner, (b) provision of one point access to both course related resources and tools associated with various learning strategies to prevent learners lost in information ‘space and technology’, (c) provision of easy and fast access to context-specific quality learning resources and tools through navigational topic maps or query-based topic maps, (d) presentation of retrieval results in a pedagogically classified style with freedom for learners to choose their own learning path, and (e) facilities for populating new resources and associated ontologies by participants, pending approval from domain experts using simple easy to use interface through topic maps-based graphic or text navigation.

The proposed approach mutually benefits both learners and teachers in many ways. Learners benefit through effective knowledge absorption through step-by-step course visualization, effective presentation of context specific annotated learning resources and freedom to choose the right resources for learning based on their level and style. A single-point access to all course-related resources prohibits learners from being side tracked from the mainstream activity. Learners can derive a sense of satisfaction to see their contribution appreciated and added to the authenticated learning object repository. Maintenance and sustainability of the learning object repository are made easy as this approach facilitates global contribution with quality check. This ensures that domain experts can focus their efforts towards authenticating rather than populating the repositories for reuse.

### 3 RELATED STUDY

The constructivist learning paradigm promotes the use of intuitively visual interfaces such as concept mapping (Novak, 1998) and topic mapping (Pepper, 2000) for effective learning. Visual representations are powerful mechanisms for materializing meaningful learning process (Gershon & Eick, 1995, Le Grand & Soto, 2000) in learning environments. Concept mapping is a “technique for representing knowledge in diagrams called ‘knowledge graphs’, which are networks of concepts with relationship between them represented respectively by nodes and links” (Novak, 1998). Concept maps are invented with the objective of externalising the understanding of a domain by learners and experts.

Topic maps represent a collection of topics, their relationships and their information sources. Topic mapping provides a mechanism for intuitively representing course concepts and their relationships between the concepts. In addition, to enable fast and easy retrieval of resources, topic map facilitate merging of electronic indexes similar to back of book index. These indexes are however, derived from multiple sources and anchored to actual resources, but kept separately.

Three key concepts are involved in topic mapping including topics, associations and occurrences (Pepper, 2000). Topics representing concepts are the syntactic constructs processable by machine. Relationships between concepts are determined by the associations with grouping of concepts without any implied direction. Occurrences are a way to binding topics to relevant resources. Such occurrence can be a resource reference such as the uniform resource locator, pdf, doc, audio, video or a string value such as population in a country. Figure 1 gives an example of a topic map in a database course.

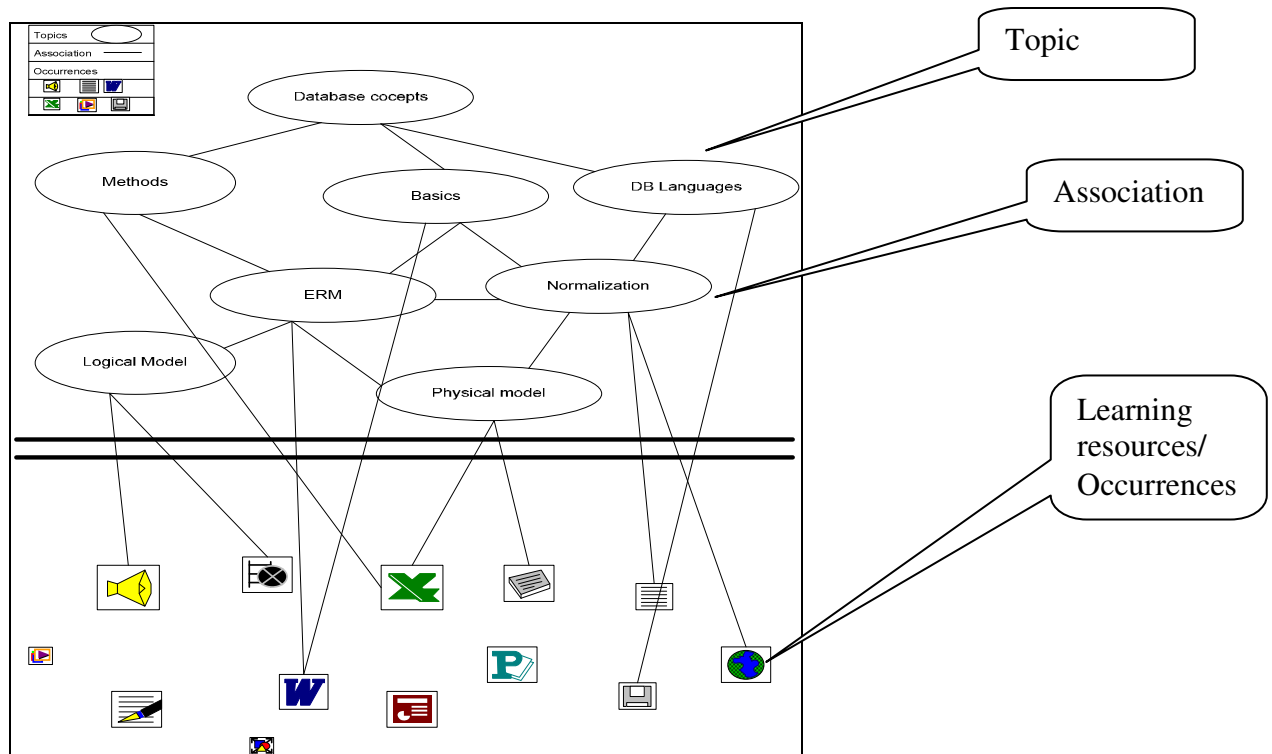


Figure 1. Example of Topic Map with topic, association and occurrence

Knowledge management is emerged to enhance the organizational performance through the synergy of people, process and technology and to address the problems of information overload. It is commonly referred to as a systematic process of acquiring, eliciting, organizing, representing and retrieving organizational information and knowledge (Nonaka, 1998, Duffy, 2001). In the current e-learning scenario, learners are often confronted with more learning resources than they can deal with or handle using various pedagogic strategies. To tackle this problem of information overload, embracing the principles of knowledge management in conjunction with the semantic web technology is imperative

for successful management of e-learning resources. The semantic web is an extension of the current World Wide Web, which envisions intelligent information processing (Berners-Lee, Hendler & Lassila, 2001).

Ontologies are “an explicit specification of a conceptualization” (Gruber, 1995) (p.908). It is the “vocabulary for expressing the entities and relationships of a conceptual model in a domain along with semantic constraints” Obrst and Liu, (2003). Ontologies are “the metadata schema providing a controlled vocabulary of concepts” (Maedche et al., 2002). Ontology is a document that formally defines the relationship among terms (Berners-Lee et al., 2006). It provides a mechanism to communicate between people and computers through a shared understanding of resources in a domain (Davies and Fensel, 2002).

There are two popular technologies for ontology construction including RDF and topic mapping. Topic mapping and RDF technologies, however, are developed with slightly different flavours for fulfilling similar objectives. Garshol (2004) asserts, “topic maps were created to support high level indexing of sets information resources to make the information in them findable. RDF, on the other hand, is intended to support the vision of semantic web through providing structured metadata about resources and a foundation for logical inferencing”. Both technologies aim at realising the semantic web vision of machine processability by annotating, associating between concepts and attaching more semantics. Topics maps are an ISO (International organisation for standardization) standard developed in 2001. RDF is a W3C (world wide web Consortium) standard developed in 1997. Web ontology language (OWL) built on RDF is the new W3C recommendation for ontology construction with facilitates for effective reasoning capabilities by consistency checking through inference rules such as transitivity, symmetry etc.

Much research in topic mapping has been done in knowledge visualization (Le Grand & Soto, 2001, Dicheva *et al.*, 2006), knowledge retrieval (Yang, 2003; Garshol, 2004; Shin et al., 2006), knowledge capturing (Dicheva and Dichev, 2006), and managing and reusing repositories (Ahmed, 2000; Dicheva et al, 2005). Several interactive graphic navigating tools and techniques for visualization through topic mapping have been developed (Mondeca, 2001, Fluit, Sabour & van Harmelen, 2002, Alani, 2003, Dicheva et al., 2005b). For instance, Topic Maps for Learning (TM4L) (Dicheva et al, 2006) provides support for graph view, text view and tree view of learning repositories. Ontopia navigator (2001), Mondeca’s topic navigator (2001), techuila’s (2001) Topic Maps for Java (TM4J) dynamic visualization (2001), and Alani’s (2003) visualization tool (TGVizTab) provide variations to existing knowledge visualization methods. Addressing the readability of a graph in a complex domain, Munzner (1997) proposes hyperbolic geometry to display large numbers of nodes in the screen. Le grand and Soto (2000) propose an interactive topic mapping visualization tool to represent semantic graphs in three dimension spaces. Nevertheless, automatic generation of graphic visualization using these tools becomes rather cumbersome and incomprehensible for a novice learner, especially in a complex course domain. In this regard, Le grand (2001) recommends topic mapping metrics to deduce efficient positioning of node to enable quick scrutiny of topic and explore the relevant ones in detail. Fluit (2002) proposes grouping instances in clusters according to their classes, while Ahmed (2000) suggests different layers of details in a topic map to display general information and to explore into details once the specificities are identified. The proposed approach adds a new dimension to knowledge representation by including topic maps based presentation of learning tools and resources based on the pedagogic classification.

Yang (2003), Shin (2006), and Vivek et al. (2007) use topic maps to enhance the retrieval of learning resources for overcoming the limitations of key-word based search engines. Yang (2003) presents mechanisms to improve the retrieval results from collaborative learning repositories in semantic retrieval of concept model (SRCM). Shin (2006) proposes conversion of topic maps and RDF metadata for effective retrieval online. Vivek et al. (2007) investigate ways to improve information retrieval capabilities in e-learning. Nevertheless, presentation of retrieved results is equally important for learners to get the best out of the resources through effective classification of retrieved results.

Dicheva (2006) builds an ontology-driven learning repository using topic mapping in TM4L ontology editor, whereas Yang et al. (2006) propose a topic map-driven visual authoring tool (XRVAT) for constructing ontologies. Ahmed (2002) examines the potentials of topic maps as an interface to multi-user document repository. Realising the problems of identification of topics and relationships between them, Dicheva et al. (2005a) highlight the importance of identification of minimal ontology using topic maps. However, facilitating global authoring with quality check is crucial aspect for creating a sustainable learning object repository, which is not given sufficient thought in the literature.

Vatant (2004), Ouziri (2006), Shih et al. (2007) and, Dicheva (2008), tackle combination of various issues related to managing repositories using topic mapping. From the technology perspective, Vatant (2007) recommends merging the potentials of OWL ontologies and topic maps to construct ontology-driven topic maps. Ouziri (2006) examines semantic integration of heterogeneous e-learning repositories whereas, Shih et al. (2007) offer organisation of learning materials through hierarchical topic maps. Dicheva (2006) supports ontology-aware repositories facilitating capture, share and access knowledge in TM4L framework. In addition, Dicheva et al. (2005) present a single access point for educational resources in ontological web portals for education (O4E). BrainBank learning (Lavik, Nordeng & Meloy, 2004) facilitates learners to map their own mental models using topic maps. Shin et al. (2006) propose a method for conversion of topic maps to RDF to avoid loss of implied semantics to enhance interoperability between topic maps and RDF whereas, Garshol (2004) proposes a model for semantic interchange between RDF and topic maps.

It is evident from the literature that a concerted effort is directed towards tackling the problem of information overload in managing e-learning resources, employing the next generation of web. Visualisation, retrieval and authoring of resources and associated ontologies using topic map is a significant development towards effective management of resources in a distributed environment. Nonetheless, generation of topic visualisation through these approaches become very cumbersome and incomprehensible, especially for a novice learner seeking to acquire knowledge in a complex domain. Besides, not much attention is paid to the representation of retrieved resources generated from multiple pedagogic strategies, which is equally important. Furthermore, global authoring, with authentication facilities, is very critical to create a sustainable learning object repository by capturing both tacit and explicit knowledge for reusability. Finally, single point access to not only to learning resource, but also learning tools will enhance the effectiveness of learning by enabling the learner to focus on the learning activity. Towards filling these gaps, this paper extends the existing research for tackling these specific aspects in an e-learning context. These aspects are simple multi-level presentation and representation of retrieved results through visual graphs, authenticated global authoring of learning resources and single point access to all learning resources including tools associated with various pedagogies.

## **4 AN ONTOLOGY-DRIVEN TOPIC MAPPING APPROACH**

### **4.1 Motivation**

The support for this study comes from our earlier work on evaluating the critical success factors for sustainable learning (Sridharan et al., 2009). This qualitative study entailed interviewing 29 academic staff involved in the e-learning domain from a wide range of function areas including the strategy and policy division, the library resource management division, the technology and media division and, the teaching experts in an e-learning environment. The objective of this study is to identify the critical success factors intertwined within pedagogies, technologies and management of learning resources in an e-learning environment. The critical success factors identified in the study include appropriate choice of pedagogies, proactive use of technologies supporting pedagogies, understanding the pedagogical principles behind technologies, appreciating and exploiting the full potentials of various technologies supporting pedagogies, effective management of learning resources through selected metadata and ontologies and, more importantly synergising pedagogies, technologies and management of learning resources for sustainable e-learning. However, it was apparent, that there are some

practical difficulties which prevent teaching staff from incorporating these factors in reality for enhancing the e-learning effectiveness. Some of the prohibiting factors identified in the study include ineffectiveness of LMS, lack of time and effort, lack of interest, problems associated with knowledge sharing etc. in proactively employing the identified critical success factors in reality. This paper addresses the specific problems related to proactive use of concept mapping technique as a pedagogical strategy, associated technologies and effective management of learning resources through ontology-based topic map approach.

In this direction, this research aims to propose a novel approach for extending the topic visualisation, representation and authoring features to fulfil specific e-learning requirements. The proposed approach consists of five modules to facilitate effective management of learning resources, namely student module, domain expert module, ontology module, authentication module and learning resources module. To comprehend the process involved in each of these modules, a motivating scenario is given in the following with a detailed explanation of functionalities of each of the modules.

## **4.2 Typical Scenario**

To illustrate the proposed ontology-driven topic mapping approach, we take a typical learning scenario, where the learner is required to accomplish a task for fulfilling the course objective. Let's take an example where the learner is expected to finish an assignment on normalization in a database course before a short deadline which is approaching. The learner is required to gather as much knowledge as possible to complete the assignment before attempting or posing any queries or doubts related to assignment. In the current e-learning set-up with LMS, the learner has to wade through multiple sources, multiple paths, and multiple modes to accomplish the task. In this scenario, despite spending a lot of time and effort, it is highly likely that learner either got side-tracked or missed some important aspects due to ineffective organisation and presentation of learning resources.

## **4.3 Student Module**

Student module facilitates a systematic presentation of topics, resources and tools in an organised manner using topic maps to enable step-by-step knowledge acquisition process for fulfilling the task. This module contains facilities for viewing the entire course in multi-levels with more details in a particular sub-topic shown on demand by the learner. Basic association types namely pre-requisite, co-requisite and follow-up concepts are represented. Learners have a choice of navigating through textual and graphical modes. Both text view and graphic view would contain the semantic overall view of the course to construe the main concepts represented by nodes in a course at a glance. Each node will have four options namely expansion, view resources, search, append within the chosen sub-topic.

By choosing the expansion option, the chosen branch will expand. The next level of details will be provided in both text and graph view. Alternatively choosing view resources option will generate a page with three frames as shown in Figure 2. The top frame of the page will contain a topic map of classified resources (such as basic learning material, collaborative learning resources, interactive learning resources, concept maps creation facilities etc.). The middle frame contains an annotated version of all relevant resources related to the chosen node from the learning object repository enabling the learner to decide their learning path. The bottom frame will contain all related tools associated with the chosen pedagogic strategy. The generated result will contain aggregated resources of all the topics based on the semantic relationship between topics represented by ontologies in the chosen node. Search option will generate the same result with classified representation of resources using both the key-word and semantic relationships from ontology structure. In addition, if learners find the resources presented to them have not clarified their understanding, they can access the query tool based on a simple web interface from the same knowledge representation sub-section to pose queries. This will automatically be directed to domain experts and peers without the need to go outside the learning space. On the other hand, if learners either found a very good learning resource or have



some queries relating to the chosen node, they can populate the learning object through a similar interface along with metadata and ontologies.

This module is linked with the ontology module and the learning object repository module for facilitating effective retrieval of context-specific learning resources. In this approach, the course structure is pre-determined and remains relatively static with the objective of keeping it simple and comprehensible to a novice learner. The ontologies and learning resources at the back end is dynamic with facilities for uploading new resources with associated ontologies. Considering that topic maps are powerful for visual representation and navigation capabilities, the use of XML (extended make-up language) based topic maps (XTM) technology is proposed for this module deriving basic knowledge structure from ontologies.

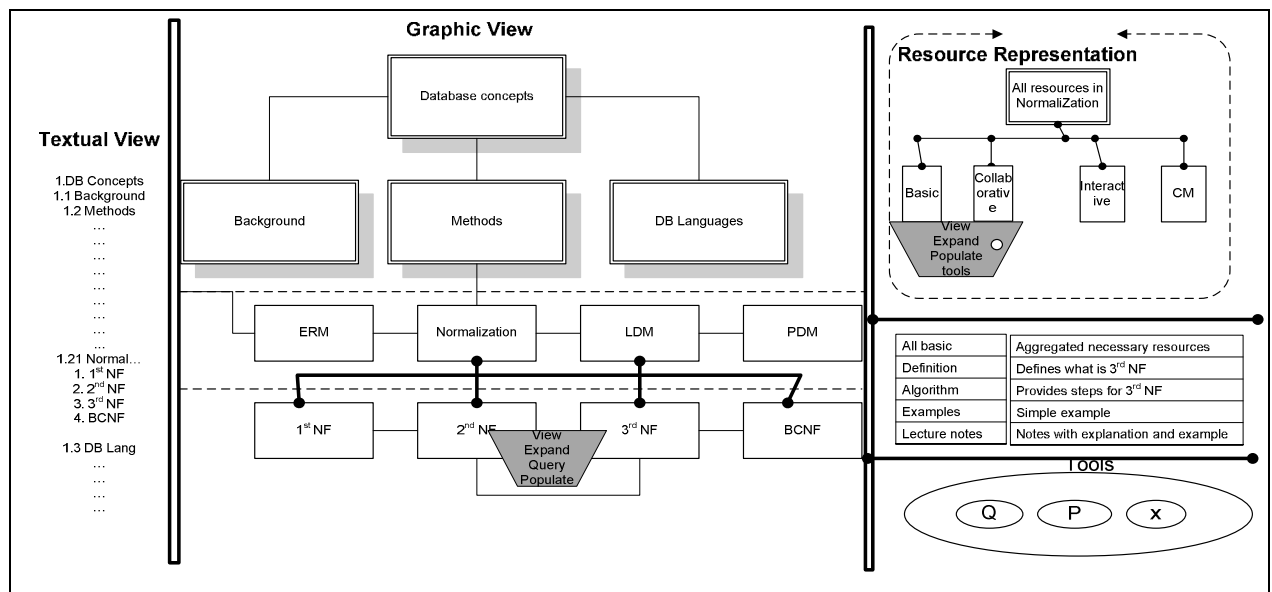


Figure 2. A multi-level learning resources visualization and representation

In the given scenario, the learner chooses the relevant node namely the normalization concept using this approach and then selects the option of viewing aggregated results or going into further details. By clicking on the view option, the system presents a categorized list of all resources on normalization and the supporting tools. The presented resource result is classified into basic resources, resources from collaborative learning such as frequently asked question, interactive learning resources such as self-test quiz and problem-based learning resources, explorative learning resources (such as open course ware material, additional reading material, useful links with annotation), tools for constructing mental maps such as concept map tools and tools for practicing problems (intelligent tutoring systems) or self-testing their knowledge. The learner can either choose aggregated result to show all resources in the chosen node and choose a specific category based on the stage of learning and preferences and styles of learning. The chosen resources will be rendered in a new page in detail with facilities for tracking of completed sections.

#### 4.4 Domain Expert Module

The domain expert module consists of simple web 2.0 based friendly interfaces for manually creating, updating, deleting topic maps along with learning resources and ontologies. The same interface is used for posting queries and answers to queries, which will automatically be added to the learning repositories after quality check by domain experts. Apart from this domain experts can create some inference rules to create automatic authentication of learning resources either based on the author, source and other selected key elements. This module is constrained by ontology module and authentication module.

## 4.5 Ontology Module

The ontology module is at the back end of the system anchored to both the visualization module and the learning resources module. This module comprises of four types of ontologies such as context ontologies, structure ontologies, domain ontologies and pedagogy ontologies. When a node is chosen or a keyword-based query is entered, the ontology base is activated to get additional information for both retrieving and classification of resources before presenting it to the learner. Using Protégé OWL, the representation of disjoint classes to assert a concept can not be instance of more than one class, consistency checking through a reasoner, and adding value restrictions can be effectively executed. Also, OWL is powerful for inference due to its expressivity and stricter rules such as transitivity, symmetry, functional properties etc. Due to these reasons, use of OWL is proposed for this module. A sample ontology construction using Protégé Owl is given in Figure 3. All the complex relationships between concepts and inference rules are included but concealed to the learner. This complex semantic relationship between concepts enables effective retrieval based on the semantically related concepts and representation of organized results.

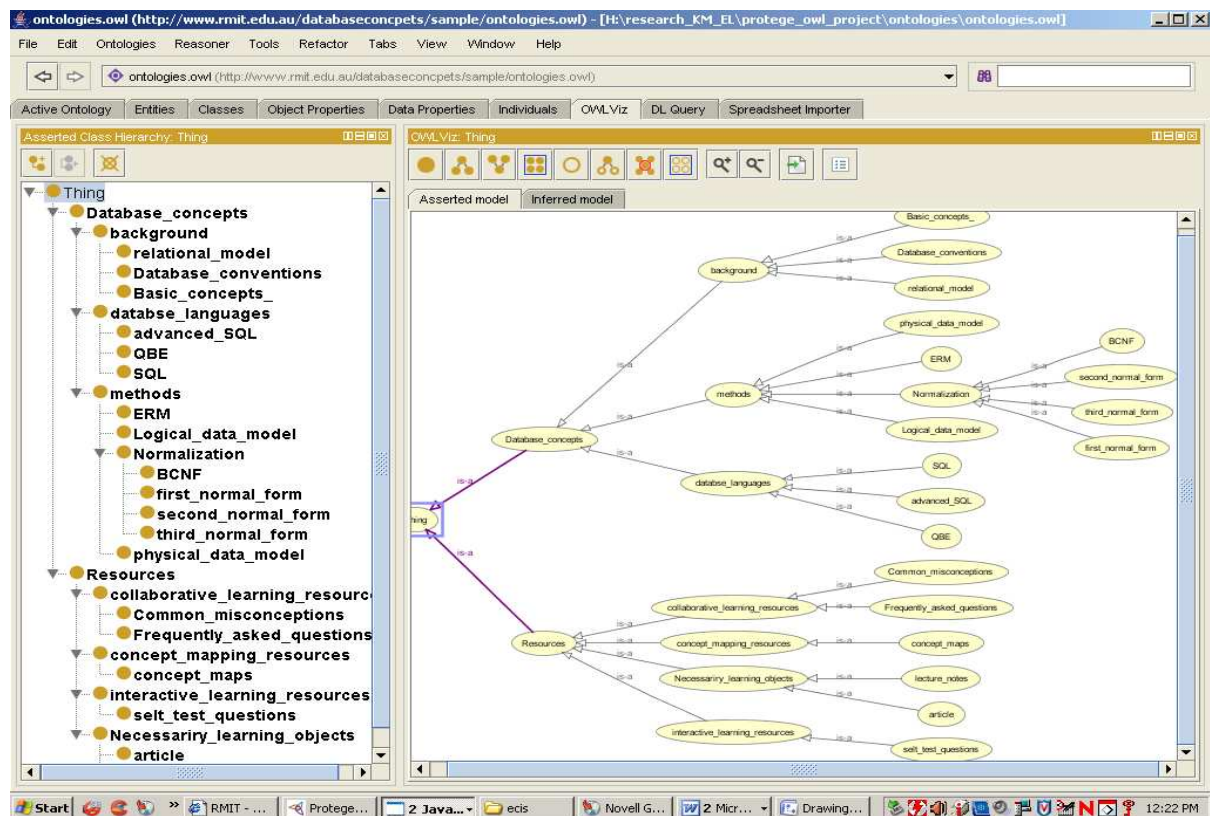


Figure 3. A sample construction of ontologies using Protégé OWL

## 4.6 Authentication Module

The authentication module is anchored to the domain expert module and the learning resource module. It facilitates either an automatic quality check based on the inference rules schema created by experts or sending alerts for domain experts to check for quality before committing the resource in the learning object repository.

## 4.7 Learning Resources Module

Finally the learning resources module contains heterogeneous learning resources which are anchored to student module, domain expert module, ontologies module, and authentication module. Use of

XTM technology is recommended to represent this module. All relevant quality learning objects are included, irrespective of the type and source of resource. The resources could be an audio, video, outside link, discussion material, question and answer, example, definition etc.

## 5 CONCLUSION AND LIMITATIONS

Having built on our earlier work in evaluating the critical success factors for sustainable e-learning (Sridharan et al., 2009), we in this paper have introduced a novel approach to overcome some of the practical difficulties in the process of embedding some of the critical success factors identified in our earlier research for successful e-learning. Specifically, we have addressed the problems associated with using concept mapping techniques, effective representation of learning resources, sustainable and reusable management of learning resources through ontology-driven topic maps in e-learning websites. This leads to some key contributions to the domain of e-learning including multi-level topic visualisation, resource representation using topic mapping, and authenticated global authoring of learning resources with critical ontologies. Furthermore, we have proposed a novel approach that is capable of recommending a single point access to not only learning objects, but also course related tools using a single interface, wherever applicable, to avoid learners losing track of their mainstream activities.

In this paper we have proposed to blending topic maps and OWL for presenting the course in a simple and comprehensive manner through topic mapping and concealing the complexities of semantic relationships in a course behind OWL ontologies. To fulfil the objective of effective presentation of course structure in a simple and comprehensible manner, a multi-level presentation of course through topic maps is pursued. To help learners grasp the basic knowledge before exploring the details of a course, high level overview of domain knowledge is proposed with expansion and collapsing facilities. To effectively represent retrieval of learning resources, this paper proposes a topic mapping based classification of resources based on pedagogies used in a course incorporating semantic annotations. To enable successful and sustainable management of learning resources, this approach proposes mechanisms for populating new resources and associated ontologies within the topic-maps based framework pending quality check by experts.

The study is limited in a number of ways. Firstly, this study is based on the outcome from a qualitative study based on a small sample size. As a consequence, generalization across the learning community is not possible. Secondly, evidence of support for such an approach is one sided as the learning community, other key stakeholders in e-learning environment, are absent. Thirdly, the success of this approach requires the identification of critical metadata and ontologies for creating a sustainable learning object repository, which has not been identified. Finally, various options and mechanisms for either developing a stand alone system or integrating with LMS and content management have not yet been explored.

Future direction for this research requires more in-depth study incorporating learners' view is critical for wider acceptance of this approach. In addition, identification of critical ontologies from teachers and learners perspectives to effectively implement a system-based on topic maps is crucial. Based on the results, development of a prototype with functionalities for presentation, representation, retrieval, authentication, inference and populating mechanisms is necessary to implement in reality. In addition, identification of mechanisms for keeping track of individual learners' progress by representing completed topics in one colour and yet to complete in a different colour within the topic map paradigm will enhance the use of the tool.

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